THE BOLL-WEEVIL PROBLEM

WITH SPECIAL REFERENCE TO MEANS OF REDUCING DAMAGE

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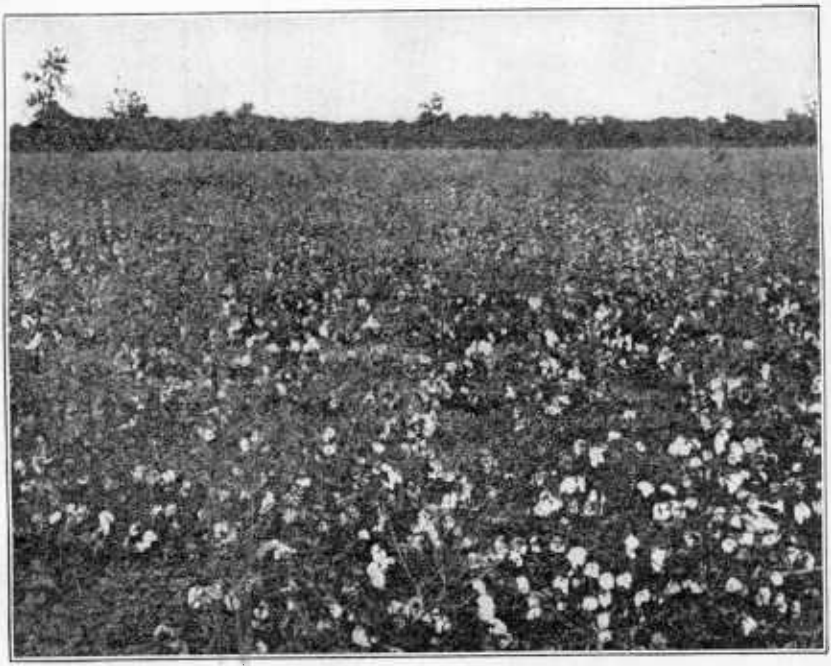

Cotton field in weevil territory producing profitable crop through proper methods

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UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

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THIS BULLETIN contains a general account of the boll-weevil problem. It deals with the history of the insect in the United States, the damage it has done in different regions, and the reasons for local variations in damage, the indications for the future, the habits of the weevil in so far as they are connected with control measures, and the means of reducing the injury it causes by methods which have been tested in many experimental fields and by large numbers of practical planters.

THE BOLL-WEEVIL PROBLEM, WITH SPECIAL REFERENCE TO MEANS OF REDUCING DAMAGE.

CONTENTS.

THIS bulletin, dealing with work done under the direction of Dr. L. O. Howard, Chief of the Bureau of Entomology, is intended to cover in a general way the whole field of control of the boll weevil, and as this control is inseparably connected with the life history and habits of the insect and, in fact, must be based thereon, attention is given to the principal features of the insect's economy. In addition, information is given relating to the amount of damage done, the extent of infested territory, and such other matters as are of special interest at this time.

Like many of the most important injurious insects in this country, the cotton boll weevil is not a native of the United States. Its original home was undoubtedly in the plateau region of Mexico or Central America, and originally it may have fed upon some plant other than cotton. This is not necessarily the case, however, since there is evidence that the same region is the original home of the cotton plant itself. Previous to 1892 the insect had spread through much of Mexico, but little is known regarding the extent or rapidity of this dispersion. The records indicate, however, that it probably had caused the abandonment of cotton in certain regions. About 1892 the boll weevil crossed the Rio Grande near Brownsville, Tex. It may have flown across, or it is possible that it was carried over in seed cotton to be ginned at Brownsville. By 1894 it had spread to half a dozen counties in southern Texas and was brought to the atten-

NOTE.—This bulletin is a revision of Farmers' Bulletin 512.

tion of the Bureau of Entomology. A preliminary examination, made under the direction of Dr. L. O. Howard by Mr. C. H. T. Townsend, showed the enormous capacity for damage of the pest. Subsequent events have verified in every way the predictions that were made at that time, when the insect had not attracted any considerable amount of attention in the South. Since 1894 the boll weevil has extended its range annually from 40 to 160 miles, although in several instances the winter conditions have been such as to cause a decrease in the infested area. During the first 10 years after its advent into this country the annual rate of spread was 5,640 square miles. From 1901 to 1911 the annual increase in the infested territory averaged 26,880 square miles. In 1916 it reached 71,800 square miles. Of course, the figures given do not refer to the area in cotton. In many parts of the infested territory the area devoted to cotton is much less than 10 per cent of the total area.

The territory in the United States in which the boll weevil was found to occur at the end of the year 1916 is shown in figure 1.

Outside of the United States the boll weevil is known throughout the larger portion of Mexico and southward to Guatemala and Costa Rica. It is known to occur also in the eastern half of Cuba.

A form of the boll weevil with different habits is found in the mountains of Arizona. It feeds upon a wild plant related to cotton. It has not been found to attack any of the planted fields in Arizona, but experiments have shown that it readily attacks the cotton plant.

DAMAGE.

The damage done by the boll weevil varies greatly from year to year and also in different parts of the infested area. As the rainfall increases the damage becomes greater. In prairie regions, where the insect obtains little protection through the winter, it never becomes so numerous as in other quarters where favorable conditions for hibernation are found. These facts, together with variations due to winter conditions, make it rather difficult to estimate the exact damage that has been done. Some years ago the writer stated, from the statistics then available, that the weevil caused a reduction of at least 50 per cent of the cotton crop in regions invaded by it, but that after the first few years the farmers generally resorted to proper means greatly to reduce this loss. Such an initial falling off in production was confirmed by Prof. E. D. Sanderson, formerly State entomologist of Texas, who arrived at his figures in an entirely different way. In many individual cases the means of control recommended by the Bureau of Entomology and demonstrated by the States Relations Service have been applied so successfully that the crop has been fully as large as before the coming of the weevil.

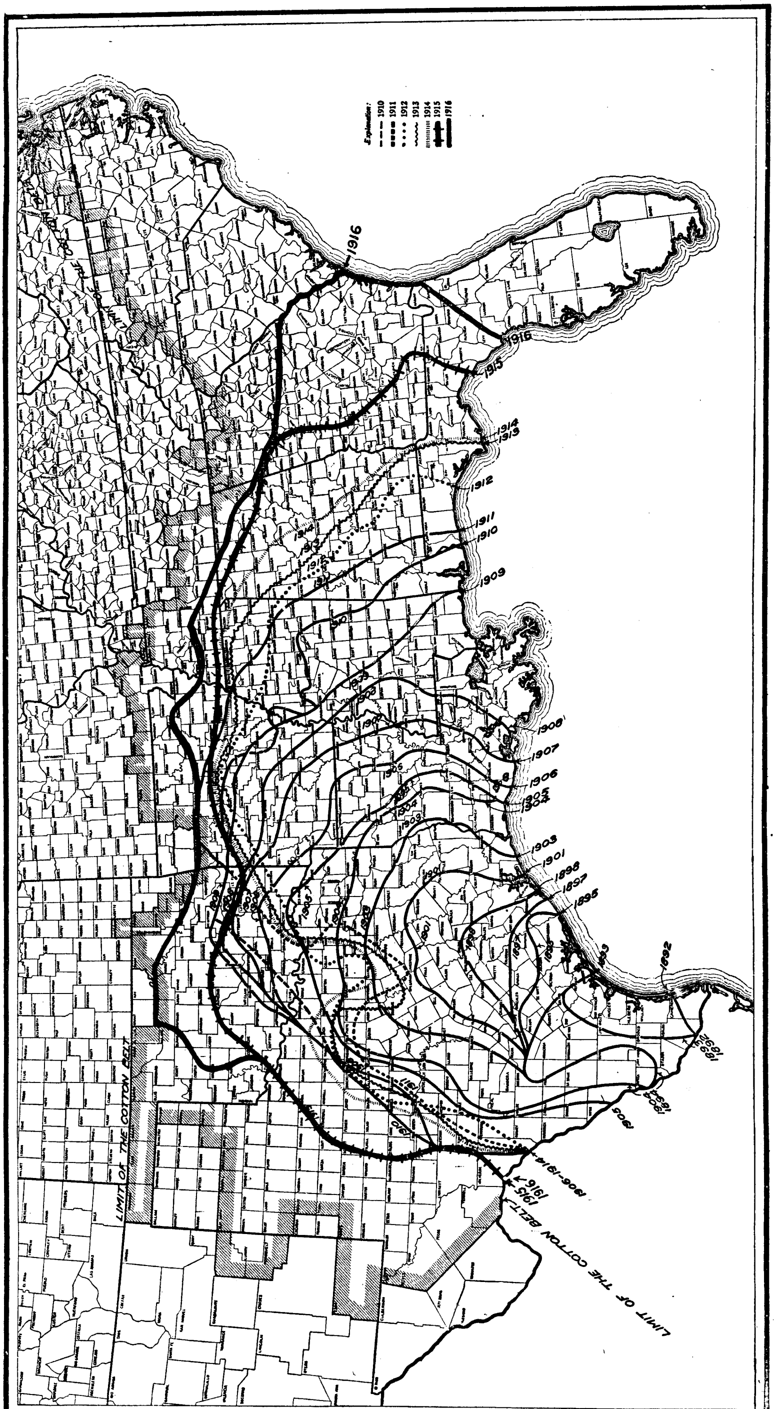

FIG. 1.—Map showing spread of the Mexican cotton boll weevil in the United States from 1892 to 1916.

The average yield per acre in Texas from 1893 to 1901 (when the weevil had not done damage sufficient to affect the general production) was 0.40 bale. The average since that time, 1902 to 1915, was 0.35 bale. By comparing these periods we have a reasonably accurate basis for estimating the damage the insect has done. The difference is 0.05 bale, or 25 pounds of lint per acre each year. At prices current through the period this means an annual loss, without considering the value of the seed, of at least $2.70 per acre which has been sustained by the cotton planters of Texas. Assuming that the area planted in cotton in Texas has averaged 10,000,000 acres, the annual loss for the State for the period from 1902 to 1915 has been $27,000,000.

Another indication of the manner in which the weevil has affected cotton production is revealed by a comparison of statistics from Louisiana and Texas. From 1899 to 1904 the acreage in Texas and Louisiana increased at about the same proportion, but the crop in Texas decreased at the same time that the crop of Louisiana was increasing. There is an exception to this statement in the years 1900 and 1904, in which the production in Texas did not decrease, but these years were exceptionally unfavorable for the weevil and at the same time very favorable for the general growth of the cotton. In 1907 the yield per acre in Texas (0.24 bale) was the smallest in history. This followed a winter so mild that more than the usual number of weevils overwintered.

Before the general invasion of the Texas cotton fields by the boll weevil, the average yield of lint per acre in that State was 187 pounds. A steady decrease in production per acre took place until 1908, at which time the production had become reduced to 175 pounds of lint per acre. In 1909 a tendency to increased production per acre began to develop. Up to 1915, however, this had not reached the average before the invasion of the weevil.

In Louisiana the production per acre before the invasion of the boll weevil was 262 pounds. Beginning with 1903 a sharp reduction began and continued until 1909, at which time the production per acre was 181 pounds. The yield per acre in this State has continued to decrease since 1909, but the falling off is not nearly as marked as for the period from 1903 to 1908.

In connection with the reduction in yield in Texas and Louisiana, it is very interesting to note a constant tendency toward increased production per acre in the eastern States. For instance, North Carolina averaged 225 pounds of lint per acre from 1895 to 1907. At that time a sharp increase in production began, reaching 285 pounds per acre in 1913. It is thus evident that the effect of the boll weevil on the production of cotton in the United States has been masked by reason of the fact that the yield per acre in the eastern cotton

States has been increasing to such an extent as to offset very largely the reduction caused by the insect elsewhere.

Undoubtedly for several years the boll weevil has caused a loss of about 400,000 bales of cotton annually. Although farmers in older regions, in many cases, are increasing their production, there is loss in the newly infested regions which offsets that gain. A conservative estimate shows that since the weevil has invaded this country it has caused a loss of 4,550,000 bales of cotton, with a value of about $250,000,000.

The figures which have been cited show clearly the enormous reduction in cotton production which the boll weevil causes. In order to make the picture complete, however, it is necessary to call attention to the effect the weevil has on the production of crops other than cotton. Wherever the insect invades a region, diversification of crops and animal husbandry receive a powerful impetus. This is shown, for instance, in the State of Mississippi. For the years preceding the advent of the boll weevil, namely, 1904–1908, the average value of all crops was $116,783,104. For the boll-weevil years, 1909–1913, the average was $132,031,800. The loss in cotton production was more than offset by the increased planting in corn, forage, and other crops. The State of Louisiana shows a similar experience. The total value of all crops from the years 1899 to 1902, during which time the boll weevil was not present in the State, was $67,394,152. During the first five years after the invasion of the insect the average value was $88,776,272. There was then a drop in values during five years of serious damage from 1908 to 1912, when the average value was $78,111,000. The reaction became complete during 1913 and 1914, when the average value of the Lousiana crops reached $94,884,472.

The criticism might be made that the statistics given in the preceding paragraphs are misleading because they deal with values which fluctuate from year to year, and not with actual volume of production. It is to be said, however, that the periods covered are sufficiently long to strike a probable average. That is to say, the fluctuations in any one 5-year period are likely to be about the same as in other 5-year periods. Moreover, the use of values is helpful on account of the bearing it has on the amount of money in circulation and consequently on the prosperity of the people. In this respect values are more suggestive than the volume of production, for the reason that large yields frequently are accompanied by low prices.

PROSPECTS.

Reference has been made to the greater damage inflicted in moist regions and where the shelter for hibernation is best. The records of the Weather Bureau show that the annual precipitation increases

very rapidly from the West to the East in the cotton belt. This is especially the case during the early growing season of cotton, namely, April, May, and June. The precipitation in the greater part of the cotton-producing area in Texas is normally about 40 inches. In Louisiana, Mississippi, and the eastern States of the cotton belt it is more than 50 inches, and sometimes exceeds 60 inches. The records that have been kept in Texas show that the damage has always been greater in wet seasons and that the insect has affected land values most where the general conditions approach those of the eastern part of the cotton belt. Without the assistance that is furnished by climatic conditions, especially dry weather during the spring, the farmers of Texas would not have been by any means so successful in producing cotton during the last few years as they have. The system of control outlined in this bulletin increases greatly in effectiveness when assisted by weather conditions. Fortunately, in Texas this assistance is given under normal conditions. When this assistance is above the normal, as in 1904 and 1906, the crops will be exceedingly large.

On the other hand, it is clear that the problem of the control of the boll weevil will be more difficult as the pest continues its invasion of the cotton belt. It can not be considered, therefore, that the problem is as yet completely solved. Better means of control must be devised for the region that is becoming invaded, and, if possible, means must be devised that will reduce the enormous loss that is suffered, especially during unfavorable seasons, in Texas. The principal work of the Bureau of Entomology at this time is in attempting to devise means for this requisite additional control.

Though the eastern planter must expect a more serious problem than that which confronted the farmers of Texas, the means of control outlined in this bulletin will enable him to continue production, though probably at a reduced profit. The sooner he adapts his plantation management to the necessary changes the less the loss will be.

Very frequently an error is made in considering that boll-weevil injury is approximately the same in localities in the same latitude. South Carolina planters, for instance, are likely to consider their situation similar to that in central Arkansas, which is in the same latitude. As a matter of fact, the activity of the boll weevil is not governed by latitude but by climatic conditions. The Gulf Stream creates conditions in South Carolina that are similar to those in regions considerably farther south, in the Gulf States. Temperature, rainfall, and the number of days in the growing season are about the same in central South Carolina as in northeastern Louisiana.

WORK UPON WHICH THIS BULLETIN IS BASED.

As has been stated, the danger from the boll weevil was appreciated from the beginning by Dr. L. O. Howard, Chief of the Bureau of Entomology. More or less continuous work on the vulnerable points in its life history and the possibility of control in various ways has been done. At first this was not extensive, although it showed the essential steps necessary in the control of the pest. Later Congress made available large appropriations for the exhaustive investigation of the insect and of means of reducing its damage. Work was begun under the first large appropriation by the establishment of a laboratory at Victoria, Tex., and the beginning of extensive field experiments. It has been the practice from the beginning to carry on field experimental work in direct connection with the laboratory investigations. Later the headquarters of the investigation were moved from Victoria, Tex., to Dallas, Tex., on account of the continued spread of the insect, and then to Tallulah, La. The Bureau of Entomology has conducted experiments during several seasons on a total of more than 20,000 acres of cotton. This experimental work has been located on well-known plantations throughout the infested territory. The special requirements in different regions have been given particular attention.

Aside from the work directly relating to the boll weevil, which has been conducted by the Bureau of Entomology, the Bureau of Plant Industry of this Department has carried on investigations in its province. These have dealt with the breeding of cottons to obtain earliness and productiveness. The farm demonstration service has carried the results of this work directly to the farmers throughout the South.

In addition to the work done by the Department of Agriculture, the States concerned have done their part. Their entomologists have dealt with the boll weevil in connection with the numerous other entomological problems of the States and have contributed valuable results which have been incorporated in this bulletin.

DESCRIPTION AND LIFE HISTORY OF THE BOLL WEEVIL.

The adult boll weevil is about one-fourth of an inch in length, varying from one-eighth to one-third of an inch, with a breadth about one-third of the length. This measurement includes the snout, which is about one-half the length of the body. Variation in size is due to the amount of food the insect has obtained in the larva stage. Individuals from bolls are therefore nearly always larger than those from squares. The color (grayish or brownish) depends upon the time that may have elapsed after transformation to the adult stage. The recently emerged individuals are light yellowish in color, but

this passes to a gray or nearly black shade in a few weeks' time. The general appearance of the insect will be evident from the accompanying illustration (fig. 2).

Many insects resemble the boll weevil more or less closely. In fact, there are hundreds of species of weevils in this country that may be easily mistaken for the enemy of cotton. Many erroneous reports about the occurrence of weevils far outside of the infested area have been due to this similarity. The only safe way to determine whether any insect is the boll weevil is to send it to an entomologist for examination. In the field the most conspicuous indication of the presence of the boll weevil is the flaring (fig. 4) and falling of great numbers of squares. Unfavorable climatic conditions and careless cultivation, however, frequently cause great shedding. If excessive shedding be noticed, and the squares upon being cut open show a white, curved grub (fig. 5) that has fed upon the contents, there is little doubt that the boll weevil is the insect causing the damage.

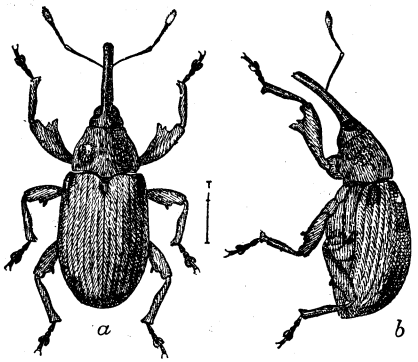

FIG. 2.—Cotton boll weevil: *a*, Beetle, from above; *b*, same, from side. About five times natural size.

The boll weevil passes the winter in the adult stage; that is, as a beetle. In the spring and throughout the fruiting season of cotton the eggs are deposited by the female weevils in cavities formed by eating into the fruit of the plant (see fig. 4). An egg hatches under normal conditions in about three days, and the grub immediately begins to feed. In from 7 to 12 days the larva or grub (fig. 3, at left) passes into its pupa stage (fig. 5, at right), corresponding to the cocoon of butterflies and moths. This stage lasts from three to five days. Then the adult issues, and in about five days begins the production of another generation. Climatic conditions cause considerable variation in the duration of the stages, but on an average it requires from two to three weeks for the weevil to develop from the egg to the adult. Males and females are produced in about equal numbers. The males feed upon the squares and bolls without moving until the food begins to deteriorate. The females refrain from depositing in squares visited by other females. This applies throughout most of the season, but late

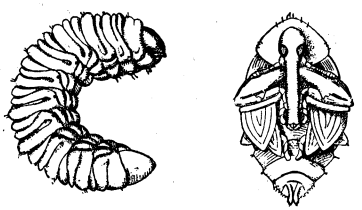

FIG. 3.—Cotton boll weevil: Larva at left, pupa at right. About five times natural size.

in the fall, when all the fruit has become infested, several eggs may be placed in a single square or boll. As many as 15 larvæ have been found in a boll. The squares are greatly preferred as food and as places for depositing eggs. As long as a large supply of squares is present, the bolls are not damaged to any serious extent. The bolls, therefore, have a fair chance to develop as long as squares are being formed.

The cotton boll weevil, so far as known at present, breeds in no plants other than cotton and the wild cotton of Arizona. This has been determined by planting various plants related to cotton in the

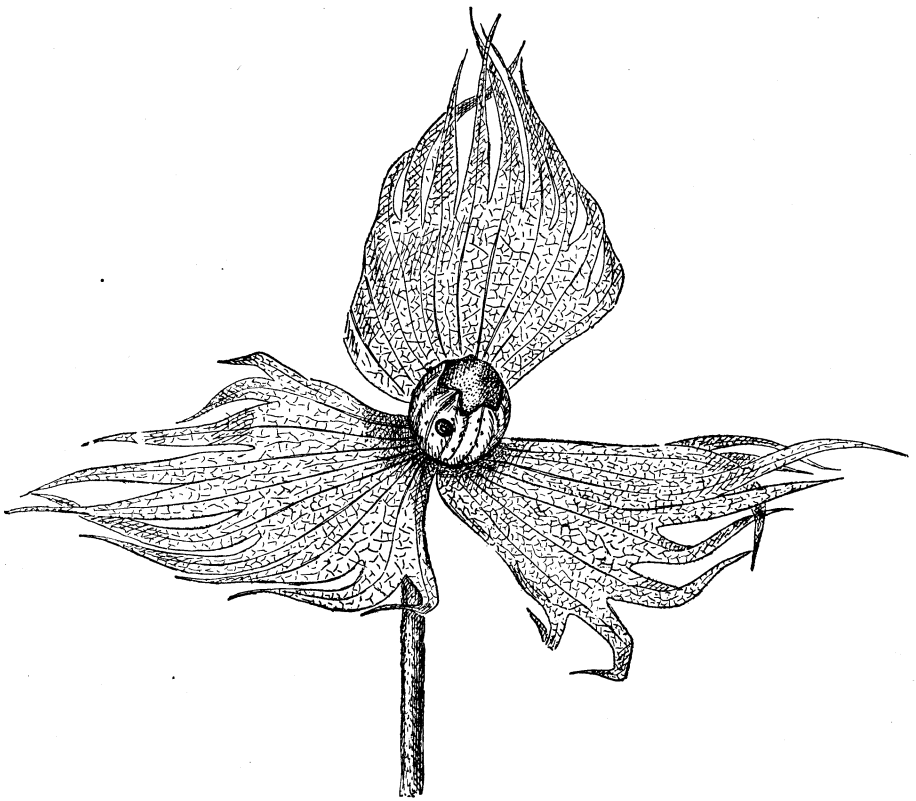

FIG. 4.—Cotton square showing egg puncture of boll weevil and "flaring" of bracts. Natural size.

vicinity of or within infested cotton fields and in cages in which weevils were placed. It has been demonstrated, therefore, beyond any doubt whatever that, at the present time at least, the insect is restricted to the cotton plant as a means of development.

In laboratory experiments performed by B. R. Coad, a weevil developed in the bud of a wild plant related to cotton. Under natural conditions it has not been found developing in that plant, but the experiments may indicate a tendency for the insect to acquire a new food plant. In the adult stage the boll weevil fre-

quently has been found in okra blooms, but repeated observations and experiments have failed to show that it places its eggs in the pods or can develop in them. When confined in bottles, the adult weevil will feed on various substances, such as apples or bananas, but this is only under the stress of starvation.

The chief activity of the boll weevil is from 9 o'clock in the morning to 5 in the afternoon. During this period it has been found in experiments performed in Louisiana that 65 per cent of the eggs are deposited. Eleven per cent of the eggs are deposited early in the morning; that is, from 5 o'clock to 9. There is some activity at night. Six per cent of the eggs were found to have been deposited between 8 at night and 5 o'clock in the morning.

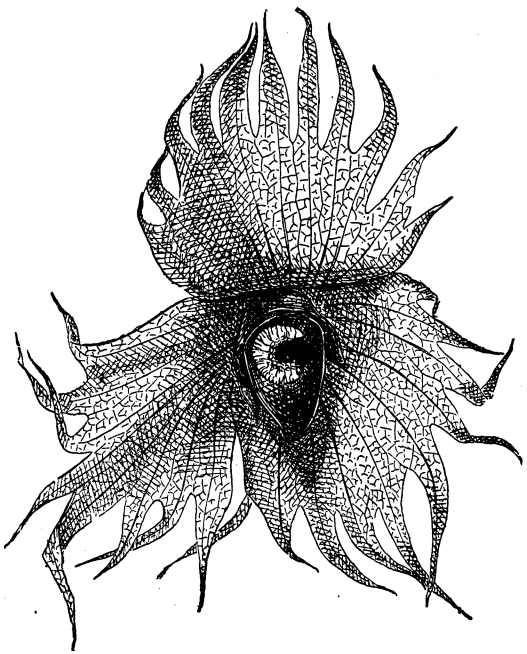

FIG. 5.—Cotton square showing larva of boll weevil in position. Natural size.

Unlike some related insects, the boll weevil is not attracted to light. The fact that somewhat similar species do come to lights in great numbers at times has frequently caused the belief that the pest could be controlled by the use of trap lights.

An interesting habit of the boll weevil is to feign death; that is, to "play possum" or "sull," as it is popularly called. When disturbed, the insects generally contract their limbs and drop to the ground. This habit is not equally strong in all individuals. It has been taken into consideration in plans of control, as will be described beyond.

The age to which weevils live varies under different conditions. During the winter the longevity is much greater than in the summer. During the summer season the majority of weevils do not live longer than 50 days. During the cooler part of the year many of them live as long as six months. The longest lived weevil on record lived from December 10 to the following October, a period of about 11 months. Undoubtedly such prolonged life is exceptional in the cases of the usual form of the weevil. The Arizona weevil, however, has been known to survive for more than a year.

HIBERNATION.

As has been pointed out, the boll weevil passes the winter in the adult stage. In the fall when frosts occur, immature stages may be found in the squares or bolls. Provided the food supply is sufficient, many of these immature stages continue their development at a very slow rate, and adults finally emerge. Thus there may be a somewhat continuous production of adults during the winter. Ordinarily, however, this is not the case, since the frosts that destroy the cotton generally kill practically all of the immature stages of the weevil.

With the advent of cool weather in the fall the adult boll weevils in cotton fields begin to seek protection against the winter. They fly from the fields in every direction, although their movements are governed partially by the prevailing winds. They may fly into hedges, woods, cornfields, haystacks, farm buildings, or other places. Specimens have been found in such situations, and also in considerable numbers in Spanish moss growing some distance above the ground on trees. A number of weevils also obtain hibernating quarters without leaving the cotton fields. These may crawl into cracks in the ground, under grass, weeds, and other trash, and into the burrs from which the cotton has been picked. In some cases several thousand weevils per acre have been found hibernating in such situations. Here, however, the mortality is greater than where the protection is better. In fact, hibernation in the fields is not of great importance except in southern localities. That the majority of weevils that hibernate successfully do not pass the winter in the cotton fields has been shown by many experimental observations and is demonstrated every year in the infested territory by the appearance of the first damage in the immediate vicinity of woods and in other places where conditions for protection are favorable.

During the winter the weevils take no food and remain practically dormant. On especially warm days they may move about to a certain extent. During the very mild winter of 1906–7 hibernating weevils were found moving about more or less throughout the period from November to March.

The number of weevils hibernating successfully has been determined very accurately for different conditions. It varies with the temperature of the winter and with the region. Heavily timbered regions, especially where Spanish moss occurs, show the smallest winter mortality. In Louisiana, out of 25,000 weevils, 2.82 per cent survived the winter of 1905–6. These weevils were placed in a variety of conditions that must have approached those which weevils must encounter naturally. The winter referred to was practically a normal one so far as temperature and precipitation were concerned. In extensive work in Texas during the winter of 1906–7, out of 75,000

weevils 11.5 per cent survived. As in the preceding case, these weevils were placed under diverse conditions in different cages. These conditions ranged from the most favorable to the least favorable; that is, from an abundance of protection to practically none. The survival obtained was undoubtedly very close to that occurring under diverse natural conditions of that winter. It must be emphasized that the winter of 1906–7 was abnormally warm. The average survival in experiments performed in Texas and Louisiana from 1906 to 1911 was 6 per cent, which must represent the average survival occurring in nature. The enormous importance of still further reducing this percentage must be evident.

Emergence from hibernation depends primarily upon temperatures in the spring, although there are other minor factors concerned. Generally, from the first to the middle of March the temperature has become high enough to cause weevils to begin to emerge. Naturally, the individuals under the heaviest protection are affected latest by the temperature. The consequence is that emergence from hibernation is a prolonged process. During one season (1906) it extended from the middle of March to the 28th of June; during another season (1907), from the middle of February to about the 1st of July. During each of these periods there was a comparatively short time—about 10 days, generally in May—of rapid emergence, preceded by an initiatory movement and followed by a period during which the number emerging day by day decreased with rapidity.

HOW NATURE ASSISTS IN DESTROYING THE BOLL WEEVIL.

Although the possible production of offspring in a single season by one pair of weevils has been estimated at 12,755,100, as a matter of fact nature has provided a number of agencies that serve to prevent such excessive multiplication. The most conspicuous of these agencies are heat and insects that prey upon the weevil.

Effects of heat.—When infested squares fall to the ground they may become so heated that the larvæ are killed in a few minutes. The insect in the larva stage can not leave the square, as it has no means of locomotion whatever. Where the infested squares are subjected to the unobstructed rays of the sun the mortality is very high. This explains the well-known fact that dry seasons are unfavorable to the weevil, and indicates great difficulty in controlling the insects in regions where precipitation is heavy. In Louisiana as many as 90 per cent of the immature weevils in cotton fields inspected have been found to be destroyed through this agency. In Texas the mortality from this cause is sometimes even higher. It was found, from examinations in many quarters, that the extent of destruction held a direct relation to the amount of shade. When there was no shade practically all of the larvæ and pupæ were killed outright.

Some of the important means of control to be described later are based upon this consideration.

Insect parasites.—The second of the important agencies provided by nature for the control of the weevil is a large number of insect enemies. These consist of a variety of forms which prey upon the boll weevil. Forty-five species of these enemies are known. Of these, 23 are parasites, which by means of their special organs place eggs on the immature stages of the weevil within the square or boll. The young of the parasite develop by feeding upon the boll weevils, which they ultimately kill. Thus parasites instead of boll weevils emerge from the injured fruit. The parasites seem naturally to be increasing in numbers and effectiveness against the boll weevil. In one instance in 1907 the mortality due to parasites in a field near Robson, La., was 77 per cent. About the same time 61 per cent of the weevils in a certain field near Victoria, Tex., were killed by parasites. These enemies of the weevil have existed in this country for an indefinite time. Their natural habit has been to prey upon weevils more or less related to the boll weevil that have occurred in this country for many years. They never feed on vegetation. It is undoubtedly true that they are now turning their attention from the original hosts, which are generally not very numerous, to the boll weevil, which offers abundant and favorable opportunities for reproduction. Thus they ally themselves with the planter for the protection of the cotton crop.

Other insect enemies.—In addition to the true parasites just described, the boll weevil suffers from a number of insects which are not parasites in a strict sense but prey upon it as food. The principal ones of these predatory enemies are ants. Of these, 12 species are known to attack the weevil. They are the minute brown ants and the yellowish ants that occur frequently in cotton fields and are observed running over the plants or on the ground. Their work is not against the adult weevils, but against the immature stages in the squares. Some species devote their attention principally to the squares that have fallen to the ground, while others habitually seek the insects within the squares that remain hanging on the plants. The larva of the weevil, incased in a thin covering, offers a source of food that the ants are not inclined to overlook. They gnaw through the thin shell inclosing the weevil larva, and the latter is soon destroyed. In some cases more than half of the immature stages in fields have been found to be destroyed by ants alone. To find 25 per cent so destroyed is not a rare occurrence.

Other factors in natural control.—In addition to the principal factors in natural control which have been mentioned there are several of minor importance. Among these may be mentioned that development of plant tissue known as proliferation, which some-

times crushes the immature weevils, and determinate growth, which may prevent the development of the fall broods of the weevil. Attention is also called to the agency of birds in the destruction of the boll weevil, which has been given full attention in the publications of the Biological Survey of this department.

DISSEMINATION.

The boll weevil moves from place to place by flight. Although it is a weak flyer compared with many insects, it has been known to cover a distance of more than 40 miles in a very short time. Its flight can not be prolonged, but successive short flights, especially in connection with favorable winds, often carry the insect to considerable distances. This is the case, however, only during the so-called dispersion period, which extends from about the middle of August to the end of the season. During the rest of the year the weevil is little inclined to fly. There is always a movement from fields in all directions in search of hibernating quarters in the fall and a corresponding movement from such quarters to the cotton fields in the spring. Nevertheless, when the insects reach cotton fields in the spring there is little further movement until the general dispersion begins. Ordinarily between the middle of August and the first of September the weevil seems to be seized with the instinct to migrate. It was thought at one time that this movement was forced by excessive reproduction and took place only when all squares and bolls, or the majority of them, became infested. Investigations have shown, however, that the dispersion takes place frequently when the fields are only slightly infested. In other words, the insect has a well-developed instinct for extending its range into new territory. It is this instinct that has caused the extension of the infested area in the United States year by year. The weevil does not fly in any particular direction except as governed by the wind. If there is no wind, or only a light one, a weevil is as likely to fly in one direction as in another. The individuals carrying the infestation into new regions are those that happen to radiate in the direction of previously uninfested territory.

The fact that the weevil moves about very little except at one season is of great benefit to the planter. As the movement referred to does not begin until after the time when a crop normally is made, it amounts to little after a region has become infested. On the other hand, the limited movement at other times of the year makes it possible for any individual farmer to obtain the best results from his own efforts in fighting the pest. The danger that his efforts will be thwarted by the arrival of weevils from fields where no precautions have been taken is not so important as it is sometimes considered. In fact, it is not important enough to warrant any farmer in deferring action on account of the indifference of his neighbors.

METHODS OF CONTROL.

It will be evident from the preceding statements regarding the life history and habits of the weevil that its control is beset with many difficulties. Its insidious methods of work in the immature stages within the fruit of the cotton plant, the habit of the adult in seeking protection for the greater part of the time under the bracts of the squares, and its enormous power of reproduction and adaptability to new conditions, all tend to place the boll weevil in a class by itself. The difficulties are increased by the necessary procedures in raising cotton. In spite of these difficulties, fairly satisfactory means of control are known. A large share of the reasonable success of the warfare against the pest is due to the assistance furnished by natural agencies, which commonly destroy many more weevils in a cotton field than the farmer could by any known method or methods.

The writer wishes to emphasize the following important points that have a direct bearing upon control:

(*1*) *The weevil has no food plant but cotton.*

(*2*) *The mortality of the weevil during the winter is very high.*

(*3*) *The emergence from hibernating quarters during the spring is slow and prolonged until well into the summer.*

(*4*) *Early in the season, on account of comparatively low temperatures, the development of the weevil is much slower than during the summer months.*

(*5*) *The drying of the infested squares soon destroys the immature stages of the weevil contained therein.*

(*6*) *The weevil is attacked by many different species of insect enemies.*

(*7*) *The weevil has little ability to emerge when buried under wet soil.*

DESTROYING INFESTED PLANTS IN THE FALL.

The process of destroying the infested plants in the fall has been recommended by the Bureau of Entomology and other agencies for many years. It is a step of the greatest general importance, though it can not be applied alike to all regions. It is of the greatest importance in southern localities, where the boll-weevil problem is most serious. In the northern portions of the infested territory it is less important on account of the effect of climatic conditions on the weevil. Its practicability depends upon the supply of labor available and upon the size of the plantings. On the very large plantations in the Mississippi Valley this difficulty is especially marked, but even in that region fall destruction can often be practiced to good advantage. It frequently happens that small portions of the field remain green and attract enormous numbers of weevils after the time when very few are to be found scattered generally in the fields. These areas are generally of such a small size that it is entirely

practicable to uproot and destroy the plants growing upon them. The greatest importance of fall destruction is undoubtedly in the southern and southeastern portions of the infested territory, where the cotton fields are small and labor is available for performing the work in ample time.

The object of the fall destruction of plants is the killing of the hordes of adult weevils that are ready to enter hibernation in the fall and the prevention of the development of millions more that would emerge later to pass through the winter. This is accomplished by cutting and burying or burning the infested plants in the fall after the weevils have become so numerous that there is no prospect of the maturity of any additional crop. There are many vital reasons why the wholesale destruction of the weevils in the fall should be practiced wherever possible. Some of these are stated here.

First.—Hordes of adult weevils, many for each plant in the field, are killed outright.

Second.—Many more weevils that are in the immature stages, sometimes as many as a hundred for each plant in the field, are also killed.

Third.—The few adult weevils escaping will be weakened by starvation, and the great majority will not have sufficient strength to pass through the winter.

Fourth. The development of the late broods, which experiments have shown furnish the vast majority of weevils that pass through the winter, is cut off immediately. In this way hundreds of weevils that would develop from each plant are prevented absolutely from so doing.

Fifth. The removal of the infested plants with the weevils facilitates fall or early winter plowing, which is the best possible procedure in cotton raising. Moreover, this plowing assists greatly in the production of an early crop the following season.

In short, in the fall the weevil is at the mercy of the planter as it is at no other time. If the planter desires to kill the insect he can do so. Work in weevil destruction at that time far outbalances all remedial measures that may be applied at all other times of the year.

Many hundreds of cases are on record showing the benefit from the fall destruction of plants in the control of the boll weevil. The process has not been taken up so generally as it should be, but individual instances everywhere show its value. A large amount of experimental work by the Bureau of Entomology has all pointed clearly toward the supreme importance of this essential method in control. In an experiment performed by the Bureau of Entomology in Calhoun County, Tex., the stalks growing on 410 acres of land were destroyed early in October. Careful records kept during the following season showed that this work had increased the production more than one-

fourth of a bale per acre over the crop on the check area where such work was not done. Computing the increase in the crop at the current prices, the advantage from the work in the experiment amounted to $14.56 per acre. This was about 29 times the cost of uprooting and burning the plants, as shown by the amount actually paid by the department for the work. Circumstances surrounding the experiment show that the advantage was probably considerably greater than has been indicated here. At any rate, the estimate given is most conservative. In this instance the cotton destroyed was isolated, and the results are perhaps somewhat more conspicuous than would have been the case where there were hundreds of cotton fields in the neighborhood. Nevertheless, experience with fields surrounded by others that have been given no attention has shown a great advantage from taking the proper step in the fall. Of course, concerted action will add to the effectiveness of the work and should be followed in every community.

In addition to the field work by the Bureau of Entomology and by many practical planters, a great deal of work has been done in large cages, where the conditions could be studied most carefully. In this way the exact relative advantage of fall destruction at different dates has been determined. It has been shown in this connection that the earlier the work can be done the better the results will be. For instance, seven times as many weevils survived the removal of the infested plants on November 12 as survived after similar work on October 13.

Mr. J. D. Mitchell, of the Bureau of Entomology, calls attention to a striking example of the value of the fall destruction of the weevils that came to his notice in Texas. On opposite sides of the Guadaloupe River, near Victoria, were two farmers, each having about 40 acres in cotton. In one case the stalks were uprooted and burned in September, and in the other they were allowed to stand until shortly before planting time the following spring. They were equally good farmers, and the soil was the same on the two places. In the first case the crop was 15 bales, and in the other 3½ bales. The work done during the preceding fall plainly increased the crop about fivefold.

No definite rule can be laid down as to the proper time for destroying the weevils upon and in the fruit of the plants in the fall. In general, the proper time is whenever the weevils have reached such numbers as to infest practically all of the squares that are being set. This may occur a month or more earlier in some seasons than in others. Fall destruction as late as November will accomplish much, but several times the number of weevils can be destroyed if the work be done in October. Therefore, the rule should be to destroy the infested plants at the earliest possible date in the fall. It is

much better to sacrifice a small quantity of cotton than to defer the operation. The loss will more than be made good by an increase in the next crop.

Objections to the work of destroying the weevils in the fall are frequently raised. The principal one is that the labor supply is insufficient to enable planters to have the crop picked out in time for such fall destruction as is recommended. One of the respects in which the boll weevil will make revolutionary changes in the system of producing cotton is that smaller areas than formerly must be cultivated by each hand. The production can best be kept up or increased by more intensive methods on smaller areas. If this principle be put in operation on plantations in so far as it is practicable, the objection to fall destruction on account of the scarcity of labor will tend to disappear. Another objection raised is that the process tends to impoverish the soil. As a matter of fact, the burning of the stalks removes only a small amount of the fertilizing elements, and, moreover, the practice now is to burn the plants a few months later. The humus is much more important than the fertilizing elements themselves.

In regions where the loss of organic matter from the burning of the stalks is important, the best advice that can be given is to cut the stalks by means of the usual machine for that purpose and bury them deeply as soon thereafter as possible. This will cause the destruction of many of the immature stages in the squares and bolls. The practice will be more effective if the land is harrowed or dragged immediately after the stalks are plowed under.

Where none of the practices recommended can be followed, it only remains for the planter to uproot the plants and leave them lying in the field. This will cut off the development of squares and thereby deprive the weevils of opportunities for breeding, while the plants remain in the field so that picking can be continued as long as may be necessary.

METHODS OF DESTROYING WEEVILS IN THE FALL.

In this connection it may be stated that the proper method, in general, is to uproot the plants by means of plows and to bury or burn them as soon as possible. Other methods are applicable to different conditions. If the plants are to be burned they should be placed in piles or windrows, which will utilize the leaves in the burning. The difficulty in one method of removing the plants—that of cutting them off near the surface of the ground with a stalk cutter or ax—is that during mild seasons many sprouts soon make their appearance to furnish food for weevils that would otherwise starve during the fall or winter. If the ordinary stalk cutter be followed immediately by plows, some of the desired results will be obtained.

The great objection is that the innumerable weevils in the bolls and squares will be allowed to develop. Nothing but uprooting and burning will fully meet the exigencies caused by the weevil, but the burning must be looked upon as an emergency measure especially necessary in regions recently invaded by the weevil and to be replaced by burying after a few years.

Plowing under infested squares.—It has been found that the weevil has little ability to emerge through wet soil. This fact can not be taken advantage of by the farmer during the growing season for the reason that deep cultivation would cause injury to the plants. In the summer or fall, however, when the weevils have become so numerous that it is evident that very little fruit will be allowed to develop, the practice can be followed to good advantage. At such times turning plows should be used, running close to the rows and thereby burying the infested squares deeply in the middles. This practice is of greatest benefit in humid regions, where the rains will soon pack the soil, and on heavy soils. In dry regions and on sandy soil it is of very little value.

Grazing.—In some cases the grazing of the fields with cattle, sheep, or goats can be practiced. This is only a local measure, however, since the supply of live stock in regions where the bulk of the cotton crop is produced is insufficient for the purpose.

Sprout cotton.—A most important result of the proper manipulation of the plants in the fall is that no stumpage or sprout cotton is allowed to grow. The occurrence of such cotton in southern Texas and occasionally in southern Louisiana is there the most important local difficulty in the control of the boll weevil. Sprout plants are sometimes encouraged on account of the production of a small but very early crop. This may have been defensible before the advent of the boll weevil, but at the present time the practice is undoubtedly the worst that could possibly be followed. The sprout plants serve only to keep alive myriads of weevils that could easily be put out of existence by the farmer.

Volunteer cotton.—In addition to stumpage cotton, volunteer cotton, in the strict sense, is of considerable importance in weevil-infested areas. The cotton seed scattered about seed houses and gins frequently gives rise to plants, both in the fall and in the spring, that furnish food and breeding places for weevils. It is needless to call attention to the fact that all such plants should be destroyed. They are merely aids to the enemy.

DESTRUCTION OF WEEVILS IN HIBERNATING PLACES.

After the weevil-infested plants have been removed from the field in the fall the planter can add strength to the blow he has given the insect. As has been stated previously, many of the hibernating

weevils are not to be found within the cotton fields or in their immediate vicinity. Nevertheless, most of those remaining in the field can be destroyed, and this is undoubtedly well worth the effort that it will cost. In many cases surprising numbers of weevils have been found hibernating in the trash and rubbish on the ground in cotton fields. In January, 1907, in one instance, 5,870 weevils to the acre were found, of which 70 per cent were alive. This was undoubtedly exceptional, but most of the many examinations made showed more than 1,000 live weevils to the acre in old cotton fields. The insects so found are largely at the mercy of the farmer. He can destroy many by carefully raking up the trash and burning it. Plowing and subsequent harrowing of the land will add to the destruction. This work would be well worth while on general agricultural principles, if no weevils whatever were destroyed. With the weevil present, that farmer invites loss who does not clean the fields to the best of his ability.

Of the multitudes of weevils that fly out of the cotton fields for hibernation, not all are beyond the reach of the farmer. Many are to be found along turn rows, fences, hedges, and old buildings. The cleaning and burning of hedges, fence corners, and in general the removal of trash from the vicinity of the fields will destroy many weevils that would live to assist in the destruction of the crop.

Old sorghum fields, on account of their roughness and the fact that the heavy stubble catches trash moved about by the wind, have been found to furnish very favorable winter quarters for the weevil. The farmer should pay special attention to such fields. They have frequently been found to be the source of the first weevils to damage the cotton in the spring. A little work in the fall or winter will result in the destruction of practically all of the weevils found there. Old cornfields, while not so important as sorghum fields, also furnish favorable hibernating quarters and should be carefully cleared by the farmer who desires to minimize the weevil damage on his place.

A very practical illustration of the danger of trash as aiding in the hibernation of the weevil occurred repeatedly on the experimental farm of the Bureau of Entomology near Dallas, Tex. Across a narrow lane on one side of the experimental cotton field of 40 acres was a small peach orchard in which the weeds were allowed to grow unchecked from year to year. Every season the first weevil infestation in the cotton was found in the immediate vicinity of the orchard. In fact, the infestation always started at that point and radiated into the field. If it had been possible to eliminate the hibernating quarters across the lane—and this meant only the prevention of the growth of weeds—there evidently would have been a considerable reduction in weevil damage, especially early in the season when it was most critical.

LOCATING FIELDS TO AVOID WEEVIL DAMAGE.

The illustration just given emphasizes a method of averting damage by the weevil that can be followed in many individual cases. All planters that have had experience with the weevil know that the portions of their properties near the timber or other locations affording hibernating quarters show the first damage by the weevil and consequently the least production. Of course, it is not always possible to plant other crops in such situations. Nevertheless, farmers frequently can avoid damage by devoting the particular fields known to be most susceptible to weevil injury to other crops. This is not pointed out as a general recommendation. In many cases it would be entirely impracticable, but its importance should be realized by planters in regions where every possible precaution must be taken.

CROP ROTATION.

Save in very exceptional cases the boll weevil never does so much damage on land where cotton follows some other crop as on land where cotton follows cotton. This is due to the fact, as has been pointed out, that the weevils do not fly very far from their hibernating quarters in the spring. Therefore it is evident that a proper rotation of crops may be followed to assist in the fight against the boll weevil. As in the case of the location of the fields referred to, the recommendation here made is no panacea. Nevertheless, rotation can be made to assist in fighting the weevil, aside from the many other advantages that are known to come from it.

PROCURING AN EARLY CROP.

Although the destruction of the weevils in the fall is the great essential step in controlling the insect, it can not be depended on exclusively. The full benefits of the fall work and the maximum crop can not be obtained unless the next great step, procuring an early crop, is taken. In fact, the success of the farmer in producing cotton in regions infested by the boll weevil will depend directly upon the extent to which he combines the various methods described in this bulletin.

There are certain localities where the conditions cause the soil to be late or slow. For instance, the planters on the Red River in Louisiana state that they can procure early crops on their "front" land, but that such is difficult or impossible on the fields back from the river. This is largely a matter of drainage. In some sections in Louisiana and Mississippi the essential step in obtaining an early crop will be largely a question of drainage. Lands so situated that they can not be drained economically to the extent that allows an early crop must be devoted to crops other than cotton.

The advantage of early planting has been demonstrated in every one of the numerous experiments made by the Bureau of Entomology and has now become the general practice among farmers. The reasons for the efficiency of early planting are not far to seek. The small numbers of weevils passing through the winter must have considerable time to multiply. They are unable to breed until squares are put on by the plants, since the food obtained from the fruit is required before reproduction can begin. Moreover, at the time the first squares are put on, the development of the immature stages is comparatively slow, not reaching the very rapid rate that obtains during the warm days and nights of the summer. For these reasons it is possible for the farmer to rush his crop in such a way that a large number of squares and bolls will be formed before the weevils have multiplied to a serious extent. The time it takes the weevils to recover after the rigors of winter, especially after the entirely feasible destruction of multitudes in the fall, can thus be taken advantage of in the production of a crop.

Removal of plants.—One step in the procuring of an early crop is the early removal of the plants, so that the land may be plowed during the fall or winter and the seed bed given thorough and early preparation. The tendency has often been to neglect the cotton fields until spring or at least until "after Christmas." In many cases it would repay the planter many times if he would take the slight additional trouble of plowing the fields before that time. Not only a plowing, but one or more harrowings should be given the land during the winter

In many regions in the South the practice of planting cover crops between the cotton rows is becoming established. This practice should be continued. The cover crops will improve the condition of the soil, and their removal will bring about the best possible conditions for an early crop. Their growth where possible is therefore much better practice than leaving the field unplanted and worked from time to time during the winter.

Fertilizers.—An important step in procuring an early crop under many conditions is the use of commercial fertilizers. In many large areas in the cotton belt the land is not impoverished to the extent that it actually needs fertilizers under normal conditions. It has been demonstrated many times by the different experiment stations in the South that the maturity of cotton frequently can be hastened materially by the use of fertilizers. On impoverished soil fertilizers containing a high percentage of nitrogen give increased yields under boll-weevil conditions.

The proper use of fertilizers is a very complicated matter. In fact, in the light of all present knowledge only the most general rules can be laid down. Each farmer must experiment with the soil or

different soils upon his own place and study the results to obtain the greatest benefit from fertilizers at the smallest cost. In the eastern portion of the cotton belt most of the farmers have acquired this experience. In the West, however, this training is lacking. Farmers interested should communicate with the State experiment stations and obtain the latest bulletins regarding experiments with fertilizers in their own regions.

The best method by far of building up soils so that early crops of cotton may be produced is the use of legumes planted either with corn or solid. In the alluvial soils of the Mississippi Valley remarkable results in obtaining increased yields under boll-weevil conditions have followed the growth of cowpeas for a single season. The planting of cover crops is also of great importance and worthy of the careful attention of all planters in the infested territory.

Use of early varieties of cotton.—Fully as important as early preparation and fertilization in obtaining an early crop of cotton is the use of early varieties. The greatest advantage in this instance comes with the joint use of the other expedients recommended for weevil control. By far the best method for obtaining seed of early maturing cotton is for the farmer to carry on the selection himself. In many cases, however, this is impracticable.

The variety to be planted in order to obtain a profitable crop under weevil conditions will depend on a number of factors. The soil, climate, and many other factors must be considered. In many localities it is extremely important to select varieties which are resistant to diseases.

What is needed is a variety which will mature quickly and set a crop by a date not later than the middle of July. In humid regions with heavy infestation the most productive varieties have been found to be King and its principal derivatives, namely, Simpkins and Broadwell. In recommending these varieties the department reminds the planter that they produce lint of a very short staple. Therefore, something of commercial value will be sacrificed. These varieties have small bolls and may safely be replaced by larger-boll varieties in other regions. The Triumph variety is one of the best known for the western portion of the infested territory. The Department of Agriculture has perfected a number of varieties which are useful in weevil territory. Among these are Lone Star, Dixie, Price, Durango, and Columbia. Other varieties which have been cultivated with success are Cleveland Big Boll, Cook's Improved, Rowden, Hawkins, Toole's, and Brown.

Wherever possible the seed should be obtained from local planters who have given attention to varietal selection. Varieties introduced from distant sources require several seasons to adjust themselves to local conditions. The use of seed simply because it comes

from a northern locality is a practice which frequently has done great injury. The only case in which the introduction of northern seed is justified is where the seed represents a variety which has been improved with reference to early maturity. Even this practice is not to be recommended except as an emergency measure when locally improved seed is not available.

Early planting.—Another step to be taken in obtaining an early crop, and fully as important as those that have been mentioned, is early planting itself. Naturally no set rule can be laid down as to the proper date for planting. There is much variation in the seasons, and sometimes it is impossible to place the fields in readiness as early as is desirable. Much of the effect of early planting is lost unless the seed bed is in good condition. Rather than plant abnormally early it would be better to improve the seed bed. It is not recommended that planting be made at dangerously early dates. Nevertheless, with proper preliminary attention to the fields it would be possible for farmers in most localities to plant from 10 to 20 days earlier than they are accustomed to at the present time. This, therefore, is the general recommendation that is made. It is much better to run the risk of replanting, provided the seed bed is in good condition, than to defer planting on account of the danger of cold weather. Of course, it is possible to plant entirely too early, so that the plants become stunted during the early days of their growth. It is not intended that planting should be done early enough to have this effect upon the plants.

Cultivation.—During the growing season of the crop the fields should be given very careful cultivations. Most of the benefits of early preparation, early planting, and fertilization may be lost in case the fields are not given the utmost attention subsequently. In case of unavoidably delayed planting the best course to pursue is to cultivate the fields in the most thorough manner possible. Under most conditions the old plantation rule "once a week and one in a row" should be made to apply. This will not result in the direct destruction of many weevils, but it causes the plants to continue uninterruptedly in their growth. By all means such operations as deep cultivation, and cultivation close to the plants, which cause shedding, should be avoided. In many instances a fair crop already set and beyond danger from the weevil has been lost by running the plows so close that the side roots were cut and the plants have shed practically all the fruit. When this happens during the middle or latter part of the season the weevils will certainly prevent the putting on of any more fruit. The general practice of laying by, by scraping the middles with a wide sweep, leaves a hard surface which causes loss of moisture and shedding. Where the weevil occurs, every precaution must be taken to avoid shedding, as the insect will

certainly prevent the maturity of the later fruit and, moreover, will be forced to attack bolls which otherwise would not be injured.

Effect of late cultivation.—There are many conspicuous illustrations of the disastrous effects of careless late cultivation. One of these occurred in Louisiana, where some planters in the Red River Valley below Shreveport were making fair crops (in one case 600 bales on 900 acres), while others were making very small yields, as, for instance, in one case 200 bales on 800 acres. Upon investigation it was found that all the planters in the neighborhood were compelled to put all their hands on levee work for five weeks to save their places. During that time the cotton remained uncultivated. After the subsidence of the flood the fields were plowed. Where this work was done carefully, good crops were being produced. In cases where the plows were run too deeply and too close to the plants excessive shedding had taken place, and the weevils prevented the putting on of any more fruit. Careful investigation on several places where the essential conditions were identical left no doubt that the cause of the difference in yields was primarily the difference in summer cultivation.

Occasionally a farmer is found who has obtained better yields on fields where cultivation has been discontinued early. In fact, the writer has seen fields full of grass that were outyielding perfectly clean ones on the same plantation. Such situations have caused erroneous conclusions. As a matter of fact, the explanation is that the late, careless cultivations had done more harm than good. The importance of careful shallow summer cultivations can not be too strongly emphasized.

SPECIAL DEVICES FOR DESTROYING WEEVILS.

The use of an arm or projection that will agitate the cotton plants has been suggested frequently. It was assumed that the knocking of the squares to the ground earlier than they would fall naturally would increase the effect of heat in destroying the immature stages of the weevil. It has been ascertained, however, that throughout much of the territory occupied by the weevil the destruction of the stages in hanging squares is much greater than in those that fall to the ground. For this reason it is evident that the best practice is to allow the squares to hang on the plants as long as they will. In addition to the effect of heat on the immature stages it is important to note that the attack of parasites is much greater in the case of hanging squares. On these accounts our advice is that cross arms or projections on cultivators should not be used except in central and western Texas, where the dryness of the climate brings about a very heavy mortality in fallen squares. In eastern Texas, Arkansas, Louisiana, Mississippi, and Alabama the mortality is greater in the hanging squares, and the planter who causes these squares to fall early merely assists the weevil.

It is sometimes claimed that the use of a crossbar will cause many of the adult weevils to be knocked to the ground, where they will be destroyed by heat. In repeated experiments in jarring and beating cotton plants in which known numbers of weevils were found it was ascertained that very few, if any, left the plants by reason of any agitation that would not break the branches or bark the stems. Occasionally, however, a weevil passing over a leaf is jarred to the ground. Entirely too much stress is often placed upon the importance of jarring the adult weevils to the ground. When specimens are collected by hand and thrown on the surface of the ground, especially if it be finely pulverized, the great majority will be killed almost instantly by the heat. This has caused the mistake on the part of careless observers of supposing that many weevils could be killed by jarring them to the ground. The difficulty, as pointed out, is that it is totally out of the question to jar more than one weevil out of many hundreds to the ground by any process that would not injure the plants severely.

The possibility of controlling the boll weevil by the hand picking of weevils and infested squares has been discussed extensively. The practice is followed by many planters, while perhaps as many others who have tested it have become convinced of its impracticability and have abandoned it.

In order to obtain exact data on hand picking, the Bureau of Entomology has performed many experiments. The original one was conducted on the lower Colorado River, in Texas, on a plantation worked by convict labor, giving the best conditions in the control of labor. No benefit followed thorough pickings twice each week for two months. In another experiment at Gurley, Tex., more than 40,000 weevils were picked on an area of eight acres by paid labor, beginning in April and continuing until July. On the eight acres where this work was done a crop of about 50 pounds per acre in excess of that on other areas was obtained. This was not sufficient, however, to pay for more than a very small fraction of the work done. Later very carefully conducted experiments were performed in northern Louisiana, sometimes in years of great weevil abundance, and sometimes when the insects were comparatively scarce. It was not found that the most thorough hand picking of weevils and squares under supervision was effective in reducing the weevils to the extent that the crop was benefited thereby.

The most important consideration in connection with the hand picking of weevils is the supply of labor. Within the last few years, especially in regions invaded by the boll weevil, the diversification of crops has received a great impetus. Areas of increasing size on most of the plantations are devoted to corn and various forage

crops. In the management of these crops considerable labor is required at exactly the same time usually considered proper for the hand picking of weevils and infested squares. It became evident in the work in northern Louisiana that only a very marked benefit from square picking would offset the use of the labor for that work when other operations were requiring attention. As no special benefit followed the picking, there is no basis for recommending the practice, at least where the conditions are similar to those in northern Louisiana. It is possible that in some other regions, where the conditions are different, it may be profitable at times to pick the weevils and squares, but this can be determined only by experiments running through a series of years, as were those in Texas and Louisiana.

It has not been found that mechanical collectors, many of which have been tested, are of any practical value. The most effective mechanical device known is the so-called hoop-and-bag, by means of which the number of weevils taken by each laborer is greatly increased. It was found, however, that this method caused considerable injury to the plants in the breaking of the lateral roots, bringing about shedding and stunted growth.

One point to be considered in this connection is that the occupation of the labor in hand picking may sometimes tend to increase its interest in the crop and improve its morale. This should be given consideration, especially in regions recently invaded by the weevil where the loss of the labor has frequently been much more important than the direct damage caused by the insect. At the same time the planter should not overlook the fact that insistence on square picking may actually disturb the labor and tend to drive it away. For example, the planters in northeastern Louisiana who attempt to follow the practice have had difficulty in preventing their negroes from going to plantations where that arduous labor is not performed.

The following extract from the "Cooperative Extension Work in Agriculture and Home Economics" (S. R. S. Doc. 36, Ext. S.) gives the views of the Demonstration Service of the department concerning the hand picking of weevils and punctured squares:

> In case it is evident that a large number of weevils have been overwintered, it may be advisable to hand pick the early appearing weevils.
>
> Persistent picking and destruction of all punctured squares both from the field and on the ground at least once each week for not less than a month, beginning when the infested squares first begin to drop, is frequently highly advisable. This is a practice of varying importance, depending upon the cheapness with which the work can be done and other factors. It is not usually advisable to continue picking up squares when there occurs very hot and dry weather during June and July, but in case of continued rains or on low, moist soils it offers practically the only hope of controlling infestation. To accomplish material results, the importance of thoroughness and beginning in time can not be overemphasized. Thorough, intensive cultivation should in no event be neglected.

TOPPING OF PLANTS.

The practice of topping plants is sometimes recommended for fields infested by the boll weevil. The results of work by different experiment stations have shown that topping has exceedingly uncertain general results. As often as otherwise it decreases instead of increasing the crop. In any case the topping of plants can probably do no harm in fields that are being damaged by the weevil. It is probable that the general results will be beneficial in causing the more rapid growth of the crop on the lower and middle branches. It has never been possible to demonstrate this in an exact way. Nevertheless, for the general effects stated, the topping of plants is included among the recommendations that should be followed, although as one of minor importance.

COTTON LEAFWORM AND BOLL WEEVIL.

The relation between the leafworm or so-called "army worm"[1] and the boll weevil deserves special attention. A quarter of a century ago the efforts of entomologists and planters were directed toward some means of destroying the leafworm. The use of Paris green was found to be effective. Various changes in the general system of cropping cotton also caused the injuries by the leafworm to become less conspicuous year after year. Even up to the time of the spread of the weevil into Texas, however, poisoning was a more or less regular operation on all cotton farms. The insects never did any considerable damage before the middle or latter part of the season. The reason for destroying the leafworm was that it prevented the maturity of a fall crop. For this reason the saving of the top crop, and in exceptional seasons a part of the middle crop, was all that was desired. The work of the boll weevil has changed all this. After the careful studies that have been given the problem, it is evident that no top crop of cotton can be expected in infested regions. This, of course, reduces the leafworm to an insect of little importance where the boll weevil exists.

The change has actually been even greater than this, for the work of the leafworm has a disastrous effect upon the boll weevil. As has been pointed out in the discussion of fall destruction, the late-developing weevils are the ones that pass through the winter. Consequently, if the leafworms defoliate the plants and stop the formation of squares, a certain degree of fall destruction is accomplished. It can never be as satisfactory as the poorest artificial fall destruction, because the plants continue to leaf out after the defoliation by the worms, thus giving the weevils a supply of succulent food. It is not recommended that the work of the leafworm be depended on in place of fall destruction. Nevertheless, allowing the leafworms to proceed with their work, or even encouraging them, will assist as a

[1] *Alabama argillacea* Hübner.

general procedure against the boll weevil, at least when, for any reasons, the more important steps are not taken. In some cases where the injury by the leafworm begins unusually early, it may still be advisable to check it by poisoning in the well-known manner, but, save in such exceptional circumstances, it will now be better to allow the leafworm to work unrestrictedly.

DESTROYING THE WEEVIL IN COTTON SEED.

It has been abundantly shown that cotton seed is of importance as a medium through which the weevil may be distributed. Many individuals that happen to be carried to the gin on the cotton pass uninjured through the gins to the seed houses. Consequently, every seed house connected with a gin in the infested territory harbors weevils, the number depending upon the amount of cleaning the staple is given. Of course, such seed is exceedingly dangerous when taken into uninfested regions. The present absolute embargoes against cotton seed from the infested region are wise. In general, they should be strictly construed. In some special cases, however, when, for instance, it is desired to obtain special improved seed, proper precaution can be taken to destroy all weevils by means of fumigation with carbon disulphid. The method is as follows:

A tight matched-board box should be provided having sides 4 feet high, open on top, and of other dimensions to accommodate 12 or more 100-pound sacks of cotton seed placed upright upon the bottom. Another tier of sacks could be added if desired. Into each one of these sacks about 1 ounce of carbon disulphid should be forced by an apparatus for volatilizing the liquid and mixing the vapor with air. The accompanying illustration (fig. 6) will give an idea of this apparatus. It should consist of three essential parts, as shown in the illustration. *A* is an air pump having sufficient storage capacity to enable it to maintain a steady discharge of air for several minutes without continuous pumping. The stopcock at a_1 regulates or prevents the escape of air, as may be desired. *B* is an ordinary 2-quart bottle fitted at b_1 with a tight stopper of good length, having two openings, through which the inlet and outlet pipes pass. These pipes may be of glass or metal and should be as large as can be used. The inlet pipe, b_2, reaches nearly to the bottom of the bottle and is provided at the lower end with a perforated metal cap, b_3, as large as will pass through the neck of the bottle. This allows the escape of the air in small bubbles and insures rapid evaporation. The outlet pipe, b_4, reaches only through the stopper. Upon the outside of the bottle is pasted a paper marked with 1-ounce graduations. *C* is a piece of ordinary $\frac{3}{8}$-inch iron gas pipe about $3\frac{1}{2}$ feet long, but this may be any desired length. It is closed and roundly pointed at the tip and for about 15 to 18 inches of its length

provided with small perforations pointing in all directions to give free escape to the vapor into all parts of the sack of seed at once.

The connections may be of rubber tubing, but as little rubber as possible should be used for this apparatus, as it is affected by the vapor of the disulphid, and the couplings will have to be replaced frequently. This, however, will not be a considerable item of expense.

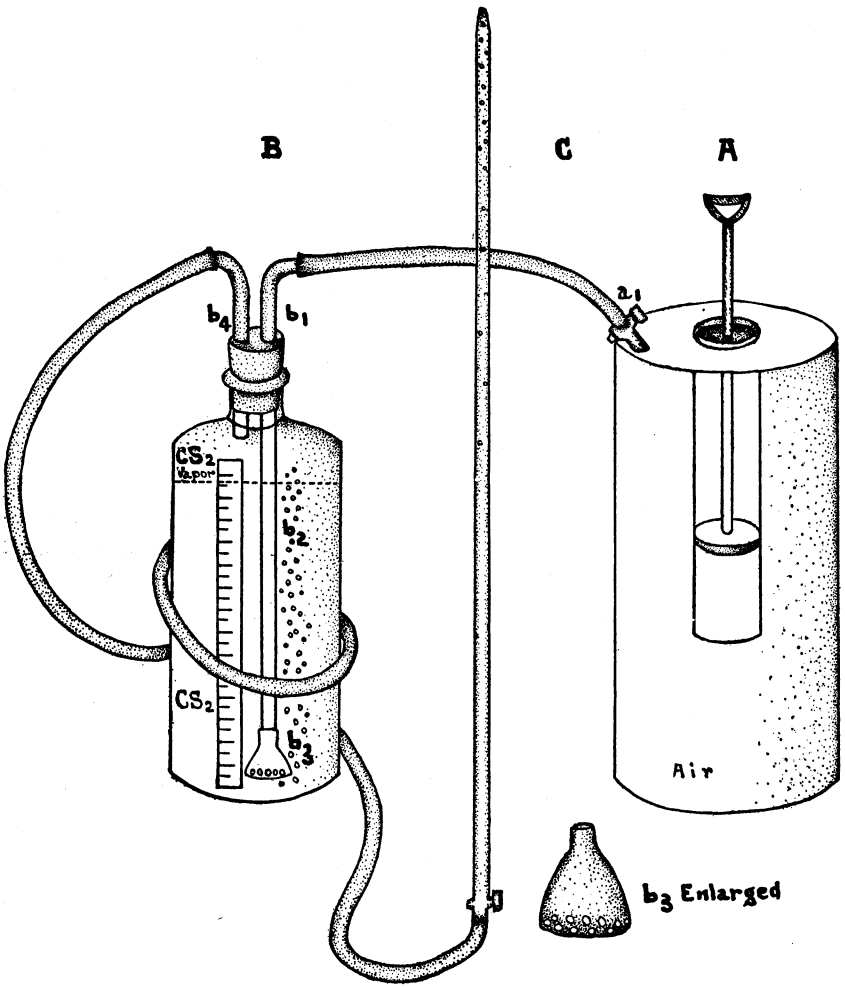

FIG. 6.—Apparatus for fumigating cotton seed in the sack.

With the apparatus just described one operator would be able to accomplish the entire work of disinfection. The amount of carbon disulphid recommended is about 1 ounce for each 3-bushel sack. It requires only from two to three minutes to vaporize 1 ounce of the liquid in the manner described. Fumigation with carbon disulphid therefore can be made effectively at slight expense.

Application of the disulphid in this manner reduces the element of danger to a minimum, as the vapor is almost wholly confined, and the slight quantity escaping, mixed with the open air, would not be in either inflammable or explosive proportions. It has been determined that the slight trace of disulphid vapor in the air would not injure the operator in the slightest degree. The sacks should be left in the box for 40 hours after the gas is injected.

RELATION OF METHODS OF CONTROL OF THE BOLL WEEVIL TO THE CONTROL OF OTHER INSECTS.

The cotton bollworm.—The most important insect enemy of cotton in the United States, aside from the boll weevil, is the bollworm.[1] This pest has existed in this country for many years and frequently reduces the crop very considerably. The annual damage to cotton in the United States has been conservatively estimated at more than $8,000,000. In addition to the injury it does to cotton, this insect is a very important enemy of corn, tomato, okra, cowpeas, and some other crops. Careful studies of the bollworm were conducted by Dr. A. L. Quaintance, of the Bureau of Entomology, in connection with large-scale field experiments in many localities. The conclusions drawn from this practical work were that the essential steps to be resorted to in the control of the boll weevil are exactly the ones that should be followed in the warfare against the bollworm. The following is the statement by Dr. Quaintance on this subject:

> The steps in the production of early cotton, outlined above, include the principal recommendations for the growing of cotton in the presence of boll weevils. It is therefore seen that injury from the cotton bollworm and the cotton boll weevil may be best avoided by the adoption of one and the same course of improved farm practice. The spread of the latter species will render imperative the adoption of these methods in profitable cotton culture, and along with this change the ravages of the bollworm during normal seasons should become less and less.

The cotton aphis.—Of the numerous minor enemies of the cotton plant in the United States there is one, the cotton aphis, or plant-louse, that occasionally may cause unusual damage by reason of early planting. This will happen to any appreciable extent only during wet seasons. Under such conditions the aphis sometimes may make it necessary to replant.[3] Nevertheless, this is not an important matter. It is not of sufficient moment to be considered at all, in view of the enormous benefit in avoiding damage by the boll weevil by means of early planting. If the other steps in the control of the boll weevil be taken, the fields made clean during the winter, and the rubbish in the fence corners and along the

[1] *Chloridea obsoleta* Fab.

[2] *Aphis gossypii* Glov.

[3] On the contrary, cases have been noticed where early breaking and thorough working caused a lessening in the number of aphids, due to the destruction of the ant that protects them. Mr. Wilmon Newell calls attention to an instance of this kind in Louisiana in 1908.

turn rows destroyed, it is not likely that the aphis will do any considerable damage, even during the coolest and wettest springs.

The injury inflicted by several other insects, such as the cotton-square borer,[1] webworm,[2] and cutworms, often makes the crop somewhat later, and consequently likely to be injured by the weevil.

GENERAL CONTROL THROUGH QUARANTINES.

There is no doubt whatever that the weevil will extend its range to the extremes of the cotton belt in this country in spite of all efforts to prevent it from doing so. The damage is so great, however, and the disturbance of economic conditions so extensive that all reasonable precautions should be taken to prevent the early accidental importation of the weevil to uninfested regions. Practically all of the States in the cotton belt have enactments designed to this end. Undoubtedly they should be enforced to the fullest extent.

At one time considerable inconvenience was caused the shipping interests by the lack of uniform quarantines in different States and the inclusion of articles in which there is very little danger of distributing the weevil. At the present time these difficulties have been largely removed. All that it is advisable to include in the absolute quarantines are cotton seed, seed cotton, cottonseed hulls, and baled cotton. These commodities are likely to carry the weevil with them. In fact, it has been amply demonstrated that the insects are frequently carried in this way. Other articles, and even empty cars, occasionally may transport weevils, but the degree of danger is so much less than in the cases of the articles specified above that they do not need to be taken into consideration.

It is entirely feasible to eradicate small isolated colonies of the boll weevil. An important office of the State authorities concerned in State quarantines should therefore be to investigate reported outbreaks of the weevil and be prepared to take the necessary steps toward eradication at the earliest moment. The Bureau of Entomology will assist the State authorities in any cases of this kind.

ATTEMPTS TO POISON THE BOLL WEEVIL.

From the very beginning of the fight against the boll weevil attempts have been made to poison it. At different times advocates of various poisons have enlisted a considerable following.

Early in the season, before squares are formed, the hibernating weevils feed on the opening leaves of the so-called bud of the cotton plant. At this time it is possible to destroy a considerable percentage by the application of poison. Exhaustive experiments performed by the Bureau of Entomology and other agencies have demonstrated that Paris green can not be used to advantage at this time. More

[1] *Uranotes melinus* Hübn. [2] *Loxostege similalis* Guen.

recent work with powdered arsenate of lead by Mr. Wilmon Newell, formerly of the Louisiana State Crop Pest Commission, seems to show that this poison can be used with profit when the plants are small and the weevils abundant. Experiments performed in Louisiana in 1909 showed that cotton treated with powdered arsenate of lead yielded an average of 71 per cent more than similar cotton which was not treated. For several years the Bureau of Entomology has been experimenting with this poison. In many cases its use has resulted in increased yields more than sufficient to offset the cost of the application. In other cases there has been a loss. It is evident that under some circumstances the poison can be used with profit by the planter. Experimental field work now under way in Louisiana is expected to show the exact practical application of this or other poisons in the control of the boll weevil.

Sweetened poisons.—Many attempts have been made to cause poisoned substances to be attractive to the weevil by introducing sweets and other ingredients. All these have failed completely. Some known sweets, such as honey, have a slight attraction for the weevil, but not enough to assist in practical control, even regardless of their expense.

Contact poisons.—Poisons designed to kill the weevils by suffocating them rather than by being taken into the digestive organs have been proposed. They can not, of course, be effective against the immature weevils within the cotton fruit. The difficulties in reaching the adults are in their manner of work. Normally these insects are found inside the bracts of the squares, where they can not be reached by sprays. In fact, nature designed the bracts to prevent the heaviest rains from reaching the square within. An additional difficulty is in the expense of applying sprays, not only on account of labor, but on account of the special machinery that is necessary. Although there is some very remote possibility that dry poisons may be found of assistance in controlling the weevil, on account of the facts mentioned it is not at all probable that liquid sprays can ever be used.

Effect of confinement.—There is one peculiarity of the weevil that has led to many unwarranted claims as to the efficacy of remedies. The insect will die within a very short time when confined in a bottle or jar, or even in a cage. Even when cages are placed over growing plants it is found that numbers of the insects die and fall to the ground, though no poison has been applied. In many instances experimenters have applied their preparations under such conditions and have found dead weevils later. They have made no allowance for the weevils that would have died under these conditions without any treatment whatever. In such experimental work special pains should always be taken to provide one or more careful checks upon the weevils that have been subjected to treatment.

FALSE REMEDIES.

The extreme seriousness of the boll-weevil problem has called forth many hundreds of suggestions in control. These have covered such methods as changes in manner of planting, attracting the insects to food plants or lights, soaking the seeds to make the plants distasteful, sprays, machines, chemical fumes, and the planting of various plants supposed to be repellent. In many cases these suggestions have been made without due understanding of the habits of the weevil. In other cases practical features, such as the cost of application, have not been considered. The following paragraphs deal with some of the principal fallacious methods that have been proposed.

Late planting.—Foremost among the futile means of control is late planting. At various times different persons have suggested that late planting, especially if following early fall destruction, would so lengthen the hibernating period that no weevils would be permitted to survive. Very numerous experiments in the field and in cages have proved that the weevils in considerable numbers are able to survive from any reasonable time of early destruction in the fall to beyond the date in the spring when any return whatever could be expected from planting cotton, even if the weevils were entirely eliminated. In a field experiment performed in Kerr County, Tex., the plants were removed very thoroughly early in November. Neither stumpage nor volunteer plants were allowed to grow during the winter. There was no other cotton planted within 9 miles. On the experimental field planting was deferred until June 10. In spite of this fact weevils appeared as soon as the plants were up and multiplied so rapidly that the production was not sufficient to warrant picking. Similar experiments carried out under different conditions by the State Crop Pest Commission of Louisiana [1] agree in every way with those obtained by the Bureau of Entomology in Texas.

The reasons for the failure of late planting are evident from a study of the habits of the insect. In many cage experiments it has been found that the last emerging weevils in the spring appear well into the month of June. In fact, emergence has taken place as late as the 27th and 28th of June. Without any food whatever the emerging weevils are able to survive for some time. The maximum known survival of any hibernated weevil without any food whatever after emergence was 90 days, and a considerable number lived from 6 to 12 weeks after emergence. This ability to survive without food, together with the late emergence, renders it entirely out of the question to exterminate the boll weevil by late planting. Moreover, there are always to be found along roads, turn rows, in cotton fields, and elsewhere, a considerable number of volunteer plants,

[1] See Bulletin 2 of the Louisiana Agricultural Experiment Station, published in 1907.

which come from seed scattered accidentally or blown from the bolls during the fall. These plants, starting early in the spring in such numbers as to be beyond control, would furnish a means for the weevils to subsist to the time of planting, regardless of how late it might be. In 1906, for instance, at Dallas, Tex., it was found that volunteer plants appeared in the spring at the rate of about 1,000 per acre. An investigation showed that the number of such plants increases to the westward as the climate becomes drier. Nevertheless, numbers of plants were found near Memphis, Tenn., and Vicksburg, Miss., in a region of more than 50 inches of annual precipitation. Similar observations have been made each season since 1906.

Trap rows.—The idea of attracting weevils to a few early plants or trap rows seemed hopeful at one time. Practical work in the field, however, has shown that nothing whatever can be expected from this method. Before many of the weevils have emerged from hibernation the planted cotton is always large enough to furnish them plenty of food. In practice it has been found impossible to defer planting long enough to concentrate any appreciable number of weevils on the trap plants. Trapping weevils to hibernating quarters is an equally mistaken idea. They can not be induced to resort to any particular places. It is likewise impossible to attempt to make the cotton fields more favorable for hibernation than places outside of the field.

There is one way in which trapping occasionally may be resorted to with good effect. When the plants are destroyed in the fall and the weather is so warm that the majority of the weevils have not entered hibernation, many of them will be found upon the plants that are left. Under these conditions the farmer can leave a few trap rows to good advantage. They should be uprooted and burned within 10 days of the time the other plants are destroyed, to kill the weevils that may be found upon them.

Attraction to lights.—Many insects more or less resembling the boll weevil are attracted to lights. This has caused many persons to attempt to destroy the cotton pest by taking advantage of the supposed habit. It has been found, however, that the boll weevil is not attracted to lights to any extent whatever. In one experiment a number of strong lanterns were placed in cotton fields in Victoria County, Tex. In all, 24,492 specimens of insects were captured, representing about 328 species. Of these, 13,113 specimens belonged to injurious species, 8,262 to beneficial species, and 3,111 were of a neutral character. Not a single boll weevil was found among all these specimens, notwithstanding the fact that the lights were placed in the midst of fields where there were millions of these insects.

Chemical treatment of seed.—It is scarcely necessary to call attention to the fallacy of attempting to destroy the boll weevil by soaking

the seed in chemicals in the hope of making the plants that are to grow from them distasteful or poisonous to the insect. Any money expended by the farmer in following this absurd practice is entirely wasted.

Other proposed remedies.—Many remedies for the destruction of the weevil, consisting of sprays, poisons, and fumigants or "smokes," have been proposed. Hundreds of these proposed remedies have been carefully investigated. The claims of their advocates in practically all cases are based upon faulty observations or careless experiments. The strong tendency of the weevil to die in confinement, which has been referred to, has caused many honest persons to suppose that the substances they are applying have killed it. Moreover, an insuperable difficulty that has been encountered in the case of these special preparations is the impracticability of applying them in the field. Hundreds of known substances will kill the weevil when brought in contact with it. The difficulty is to apply them in an economical way in the field. A striking instance of the unwarranted claims of some discoverers of "remedies" for the weevil was the case of a man who demonstrated the efficacy of his preparation by placing a feather in the bottle containing it and applying this to a weevil in his hand. Of course the death of the weevil was very far from a demonstration of the practical working of the supposed remedy. The claims made at different times of the repellent power of tobacco, castor-bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

Mechanical devices.—Many machines have been constructed to collect the weevils from the plants, or the bolls and squares from the ground. These have consisted of suction and jarring devices. Many of them will destroy a certain number of weevils, but the habits of the insect are such that none has been found to yield results that pay even a small portion of the cost of operation. It is emphasized in this connection that there are plenty of proper ways in which all available mechanical ingenuity may be utilized in the fight against the weevil. There is great need for effective machines for assisting in the destruction of the weevils in the fall, and also for assistance in the cultivation of the crop. The present implements for cultivation, while effective in their way, could be improved in many respects, especially for the purpose of hastening the maturity of the crop. For instance, cultivators to establish a dust mulch rather than to plow the ground are much needed. There are some cultivator attachments, such as the spring-tooth attachment, which are exceedingly useful tools in maintaining a surface dust mulch, but these are not as yet in general use.

SUMMARY OF CONTROL MEASURES.

The following is an outline of the practical methods of controlling the boll weevil described in detail in the preceding pages. These methods are based upon extensive studies and much field experimentation. They represent practically all that is known about combating the most important enemy of the cotton plant. They form a system consisting of several parts. The planter can insure success in proportion to the extent to which he combines the different essential parts.

(1) Destroy the vast majority of weevils in the fall by plowing under or by uprooting and burning the plants. This is the all-important step. It results in the death of millions of weevils. It insures a crop for the following season. If it is not practicable to burn the stalks, they should still be uprooted. This will stop the development of the weevils but allow the cotton to be picked as the supply of labor permits. If the plants can not be uprooted, turning plows should be used in humid regions to cover the fallen squares deeply as soon as the fields become heavily infested in the summer or fall. The practice is of little value in dry regions, but in humid regions it will result in the death of many of the weevils in the buried squares.

(2) Destroy also many weevils that have survived the preceding operation and are found in the cotton fields and along the hedge-rows, fences, and buildings. This is done by thoroughly clearing the places referred to. (See pp. 21–22.)

(3) So far as possible, locate the fields in situations where damage will be avoided. This can not be done in all cases, but frequently can be done to good advantage.

(4) Prepare the land early and thoroughly in order to obtain an early crop. This means fall plowing and winter working of the land or the use of cover crops.

(5) Determine the best distances between the rows and between the plants by experiments on local soils. In general, proper spacing for large production before the coming of the weevil will be found most favorable for a large crop.

(6) Insure an early crop by early planting of early-maturing varieties, and by fertilizing where necessary.

(7) Continue the procuring of an early crop by early chopping to a stand and early and frequent cultivation. Do not lose the fruit the plants have set by cultivating too deeply or too close to the rows.

(8) Do not poison for the leafworm unless its work begins at an abnormally early date in the summer.

(9) Do not go to the expense of buying special preparations for destroying the weevil. Disappointment and loss are certain to fol-

low. In case of doubt communicate at once with the Bureau of Entomology or with the entomologist of the State experiment station.

SPECIAL TREATMENT OF SMALL AREAS.

In some cases where, for instance, a farmer has a small area of cotton growing for seed selection, it is practicable to resort to special means of control that would be impossible in general field practice. For the benefit of the many farmers in the infested area who are beginning to improve their cotton by selection, the following suggestions are made: The plat or plats should be far from timber, hedgerows, seed storage houses, and other protection for hibernating weevils. On the appearance of the earliest weevils the plats should be carefully picked over by hand. This should be continued until well after the squares begin to fall. If the falling of the squares continues, it will be found practicable to rake them by hand to the middles or entirely outside of the plats to a bare place, where the sun will soon destroy the larvæ within. Of course, all other general suggestions that are applicable in the field should be added to these special ones.

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